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EEDP-01-3  
February 1987



# *Environmental Effects of Dredging Technical Notes*



## ENGINEERING CONSIDERATIONS FOR CAPPING SUBAQUEOUS DREDGED MATERIAL DEPOSITS -- BACKGROUND AND PRELIMINARY PLANNING

**PURPOSE:** The following two technical notes present information applicable to planning and constructing dredged material capping projects:

EEDP-01-3 Background and Preliminary Planning

EEDP-01-4 Design Concepts and Placement Techniques

This first note identifies and reviews field experiences with subaqueous capping of dredged material and discusses aspects of site selection.

**BACKGROUND:** In recent years the search for alternatives to expensive and limited upland containment areas for contaminated sediment has centered on in-water capped disposal. This interest was further reinforced when the convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Dumping Convention) accepted the capping concept, subject to monitoring, as an appropriate technology for rapidly rendering harmless the contaminants of concern in dredged material. Subsequent detailed investigations (e.g., Brannon et al. 1985, O'Connor and O'Connor 1983) have confirmed that capping can be effective in chemically and biologically isolating contaminated dredged material from the overlying aquatic environment.

However, in order to ensure this effectiveness, capping projects cannot be treated simply as a modification of conventional disposal practices. A capping project must be thought of as an engineered structure with design and construction requirements that must be met, verified, and maintained over the design life. This is not to say that traditional equipment and operational methods cannot be applied to capping contaminated materials. In fact, they have been used with good success. Technologies must, however, be applied in a systems context and with careful control and monitoring.

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AQM00-11-3717

## The Capping Concept

A simple definition of in-water or subaqueous capping is the controlled accurate placement of contaminated materials at a disposal site, followed by a covering or cap of clean isolating material. Figures 1 and 2 are schematics of

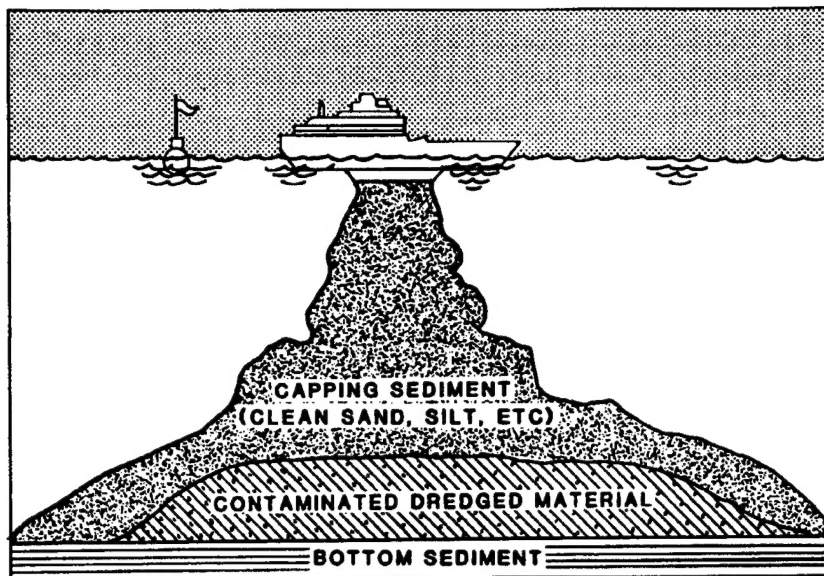


Figure 1. Schematic of typical level-bottom capping operation (adapted from Shields and Montgomery 1984)

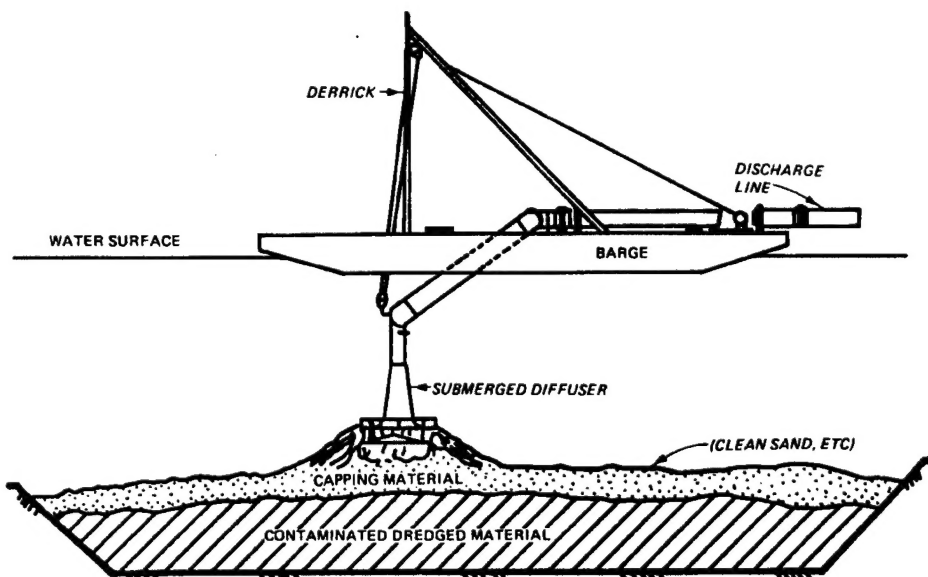


Figure 2. Schematic of contained aquatic disposal (CAD) project also showing use of a submerged diffuser for placement

two types of capping projects, level-bottom capping and contained aquatic disposal (CAD). As the name suggests, level-bottom capping projects attempt to place a discrete mound of contaminated material on an existing flat or very gently sloping natural bottom. A cap is then applied over the mound by one of several techniques, but usually in a series of disposal sequences to ensure adequate coverage. CAD is generally used where the mechanical properties of the contaminated material and/or bottom conditions (e.g., slopes) require positive lateral control measures during placement. Use of CAD can also reduce the required quantity of cap material and thus the costs. Options might include the use of an existing depression; preexcavation of a disposal pit; or construction of one or more submerged dikes for confinement.

It is evident that capping projects must be characterized by a high degree of interaction among various operational factors. Table 1, from Shields and Montgomery (1984), demonstrates these interrelationships and emphasizes the need for a systems approach to planning.

TABLE 1. Considerations for Planning Capping Operations

Number	Decision	Impacted by Decision
	Description	
1	Dredge equipment selection	
2	Selection of disposal and capping site	
3	Placement method for contaminated material	1,2
4	Method for transporting contaminated material to disposal site	1,2,3
5	Selection of capping material	1,2,3,4
6	Placement method for cap	1,2,3,4,5
7	Dredge plant for obtaining cap material	1,2,3,4,5,6
8	Method for transporting cap material to disposal site	1,2,3,4,5,6,7
9	Method for navigation and positioning at site	2,4,8
10	Method for monitoring site	2,9

#### Overview of Existing Capping Projects

Field experience with subaqueous capping is certainly limited in comparison to the decades of upland disposal site design. However, a sufficient

number of capping projects have been completed to establish that the concept is technically and operationally feasible. Table 2 describes the salient features of the major capping projects reported in the literature.

#### Level-bottom capping projects

The majority of the reported projects were the level-bottom design in which contaminated fine-grained sediment was excavated by mechanical dredge and placed by conventional bottom-dumping barges or scows. The cap material was typically silt and/or fine sand that was placed over the mounds by either scows or a conventional hopper disposal. None of the reports noted any difficulty in producing well-defined discrete mounds.

In general, descriptions of the projects indicated that the sediment formed a very steep-sided central mound with a radius of 400-500 ft and a height of several feet (Table 2). Following a sharp break in slope, material continued in a deposit up to several inches thick over an annular area extending an additional 400 to 500 ft. In these projects, no attempts were made to cover the mound with a cap of uniform thickness. Coverage was achieved by point placement of relatively large volumes (at least 2 to 3 times the underlying mound volume) of capping sediment. In the few reported cases where, in the opinions of the investigators, the disposal project was not considered entirely successful (e.g., Central Long Island Sound Cap Site No. 1 and No. 2), the difficulties were traced to problems with positioning or control rather than to equipment or design.

In summary, experiences at several heavily monitored level-bottom capping projects indicate that mechanically dredged sediment can be deposited in discrete mounds and successfully capped. Conventional equipment and operational techniques can be used, provided special attention is given to precise positioning and overall control of the operation.

#### CAD projects

Design objectives. Applications of the CAD design have been limited; and, because the projects involved variations in equipment and technique, generalizations are difficult. As noted, CAD is typically used where positive lateral control of a contaminated dredged material is desired during placement. In planning these types of projects, it is important to clearly identify the reasons for the desired increase in confinement so that proper alternatives are evaluated.

Three existing CAD sites are listed in Table 2; however, in none of the

TABLE 2. Descriptions of Capped Disposal Projects from the Literature

Project		Contaminated Material				Capping Material			Data Source
Location (Date)	Site Characteristics	Volume of Material yd <sup>3</sup> *	Dredging Method	Placement Method	Volume, yd <sup>3</sup> * (Type)	Thickness of Cap, ft	Placement Method	Positioning Method	
Duwamish Waterway Seattle, WA (1984)	Existing subaqueous depression ~70 ft deep	1,100	Clamshell	Scow	3600 (sand)	1-3	Sprinkling from scow	Surveying instruments	Truitt 1986, Sumeri 1984
Rotterdam Harbor, The Netherlands (1981-1983)	Phase I: Botlek Harbor Excavated to ~98 ft deep Phase II: 1st Petroleum Harbor Excavated to ~80 ft deep	1,200,000 620,000	Trailing suction hopper Matchbox suction	Pumpout-submerged diffuser Pipeline submerged diffuser	- - (clay) - - (clay)	2-3 2-3	Scow, then leveled over site Scow, then leveled over site	Surveying instruments	d'Angremond et al. 1986
Hiroshima Bay, Japan (1979-80)	Contaminated bottom sediment overlaid in situ with capping material ~70 ft deep	N/A	N/A	N/A	- - (sand with shell)	1.6	Conveyor to gravity-fed submerged tremie	Surveyed grid and winch/anchor wires	Kikagawa 1983
New York Bight (1980)	Generally flat bottom ~80-90 ft deep	860,000 (mounded to 6 ft thick)	Clamshell	Scows	1,800,000 (majority fine sand)	Average 3-4 Maximum 5-9	Scow, hopper dredge	Buoy, real-time navigation electronics	Freeand 1983, Mansky 1984, O'Connor and O'Connor 1983, Suszkowski 1983
Central Long Island Sound Disposal Area (1979)	Stamford-New Haven, North Generally flat bottom ~65 ft deep	34,000 (mounded 3-6 ft thick)	Clamshell	Scows	65,400 (sand)	up to 7-10	Hopper dredge	Buoy, Loran-C coupled positioning system	Morton et al. (eds.) 1984, O'Connor and O'Connor 1983
(1979)	Stamford-New Haven, South Generally flat bottom ~70 ft deep	50,000 (mounded 4-6 ft thick)	Clamshell	Scows	100,000 (cohesive silt)	up to 13	Scow	Buoy, Loran-C coupled positioning system	

(Continued)

\* All volumes are approximate, usually based on estimated in-scow measurements. Dash entries indicate volume of capping either unknown or not reported.

**TABLE 2. Descriptions of Capped Disposal Projects from the Literature (Concluded)**

Project		Contaminated Material			Capping Material				Data Source
Location (Date)	Site Characteristics	Volume of Material yd	Dredging Method	Placement Method	Volume, yd <sup>3</sup> (Type)	Thickness of Cap, ft	Placement Method	Positioning Method	
Central Long Island Sound Disposal Area (1979) (Continued) (1981)	Nowalk Generally flat bottom ~65 ft deep	92,000 (multiple mounds up to 8-12 ft thick)	Clamshell	Scows	370,000 (silt and sand)	up to 6-7	Scow	Buoy	Morton et al. (eds.) 1984, O'Connor and O'Connor 1983
(1982-3)	Mill-Quinnipiac Generally flat bottom ~65 ft deep	40,000	Clamshell	Scows	1,300,000 (silt)	Multiple broad area placement. Estimated final avg 6-10	Scow	Buoy	
(1983)	Cap Site No. 1 Generally flat 60 ft deep	33,000 (mounded 3 ft thick)	Clamshell	Scows	78,000 silt	Incomplete coverage	Scow	Buoy, Loran-C	
(1983)	Cap Site No. 2 Generally flat ~56 ft deep	40,000 (low mound, 2 ft thick)	Clamshell	Scows	40,000 sand	Irregular - maximum 4.5, areas as little as 0.6	Scow	Buoy, Loran-C	

three did the engineering characteristics of the dredged material directly dictate the use of a CAD design. The principal design influence in these projects was the need to produce a disposal site with sufficient volume below navigable depths in an existing waterway. The secondary objective was to reduce the number of migration pathways through which contaminants could find their way into the environment (i.e., increase the contaminant isolation).

The interactive processes shown in Table 1 were particularly demonstrated in the Rotterdam Harbor projects (d'Angremond, de Jong, and de Waad, 1986). The use of the CAD alternative provided the required volume within existing waterways and reduced the total number of contaminant migration pathways. However, because the depth of the excavation would have placed the contaminated material closer to critical groundwater resources, that single pathway actually became the greatest concern and resulted in a decision to deposit clay to line the excavation as well as to cap the contaminated material. But the decision to use CAD also allowed dredging to be performed by a hydraulic dredge with pipeline transport at significant time and cost savings.

Cap placement at existing CAD sites. The method and/or rate of placing capping material over a CAD site, especially one in which hydraulically dredged sediments have been disposed, has been cited as a concern. Point dumping of cap material over these unconsolidated deposits is likely to result in displacement of the contaminated material. The reviewed projects in Hiroshima Bay (Togashi 1983 and Kikegawa 1983) demonstrated technologies that have application to this problem. Both projects involved the overlaying of contaminated bottom sediment in situ with clean capping sand. In one case, a telescoping tremie (gravity-fed downpipe) was extended through the water column and capping sand fed into it by a conveyor/barge system. In the second test, a submerged spreader bar with diffuser ports was used to apply the cap. Both projects resulted in the controlled placement of a uniform cap approximately 20 in. thick.

The Duwamish Waterway capping project (Sumeri 1984, Truitt 1986b) demonstrated the use of a conventional split-hull barge with operational modifications to place the cap. Contaminated sediment had been dredged mechanically and accurately placed in an existing depression used as the CAD site by a precisely positioned and controlled barge operation. The cap was then placed by incrementally opening, over a period of tens of minutes, the split hull of another barge filled with clean sand. The sand exited slowly and was



sprinkled through the water column onto the site. Dispersion was minimal and three discrete, but overlapping, disposal sequences were used to ensure adequate coverage.

A third procedure was tested in the Rotterdam Harbor projects. At these sites the excavation of the CAD areas produced a surplus of clean cohesive clay that was incorporated into the design to be used as a reduced permeability capping material. The combination of unconsolidated hydraulically-placed contaminated sediment and the very cohesive mechanically dredged capping material precluded conventional point dumping of the cap. Barge loads of the clay were deposited on the bottom adjacent to the disposal site and the material subsequently raked over the contaminated sediment using a towed drag. This technique is not recommended because of the localized increase in suspended solids during construction, but it did demonstrate that a cap could be effectively placed and supported.

#### Considerations for Capping Site Selection

At least six considerations can be identified that are important in evaluating the engineering acceptability of a proposed open-water dredged material disposal site:

- Bathymetry (bottom contours)
- Currents (velocity and structure)
- Average water depths
- Salinity/temperature (density) stratifications
- Bottom sediments
- Operational requirements (location/distance, surface sea state, etc.)

In general, these considerations are no different for a site intended for capping. Probably the most important (physical) goal in selecting an open-water site for disposal and capping of contaminated dredged material is long-term stability of the deposited material. However, site selection normally involves a compromise or trade-off among the desirable criteria for each site characteristic.



### Influence of Site Conditions on Capping Projects

Bathymetry. If the bottom in a disposal area is not horizontal, a component of the gravity force will influence the energy balance of the bottom surge. It is difficult to estimate the effects of slope alone, since bottom roughness plays an equally important role in mechanics of the spreading process. Gordon (1974) described the results of monitoring barged disposal operations at a level bottom site on Long Island Sound and concluded that 81 percent of the original volume of sediment released was deposited within a radius of 100 ft from the point of impact and 99 percent was deposited within a radius of 400 ft. Disposal into an existing depression approximately 150 by 300 ft was monitored during the Duwamish capping demonstration project (Truitt 1986b). Measurements of sediment in the water column at a distance of 100 ft from the center of impact showed that 93 percent of the original mass could be accounted for within this radius and confirmed the positive effect of using existing or constructed confining features at a disposal site.

Currents. Basic current information should be collected at prospective disposal sites to identify site-specific conditions. However, based on observations at several sites, Bokuniewicz et al. (1978) concluded that the principal influence of currents in the receiving water is to displace the point of impact of the descending jet of material with the bottom (by a calculable amount). They stated that even strong currents observed at a Great Lakes site need not be a serious impediment to accurate placement, nor do they result in significantly greater dispersion during placement. Further, currents do not appear to affect the surge phase of the disposal (see Truitt (1986a) for a description of the overall disposal processes at open-water sites).

Long-term effects of currents at a prospective site may still need to be investigated, and little information is available on the transport of sediments from disposal mounds. Storm-induced currents are also of interest in the long-term stability of the site. However, disposal operations would be halted during storms, so the designer need consider only near-bottom currents not water-column currents. Measured current data can be supplemented by estimates for external events using standard techniques; e.g., see the Shore Protection Manual (Coastal Engineering Research Center 1984).

Average water depths. Aside from the effect that depth has on currents, there appears to be little additional short-term influence on disposal.

Bokuniewicz et al. (1978) observed the same general physical processes resulting from placement of dredged material at different sites with water depths ranging from approximately 50 to 200 ft. In deeper water, more entrainment occurs in the descent phase, and there is more bulk dilution of the dredged material before it reaches the bottom. However, there is no increase in the jet impact speed, nor does the bottom surge spread at a faster rate. The initial thickness of the spreading surge above the bottom has been shown to be a function of water depth. Again, the total water depth at a site has more favorable impact on long-term stability than unfavorable impact during the disposal process.

Salinity/temperature (density) stratification. A sufficiently great density gradient in sufficiently deep water can result in arrest of the descending jet. The depth at which this occurs can be calculated. Bokuniewicz et al. (1978) suggested that although highly stratified conditions may be encountered, it is most unlikely that water depths would be great enough at most sites to cause collapse in the upper water column. Johanson, Bowen, and Henry (1976), reporting on work discussed by Brooks (1973), presented a simple empirical equation to estimate when a descending jet would penetrate a stratified layer. In addition to the relative differences in density, the depth to the interface of the density layers in the water column (not total water depth) and the initial volume of the jet are the important terms.

Operational requirements. Among the operational criteria that should be considered in evaluating potential capping sites are: volumetric capacity of site; nearby obstructions or structures; haul distances; bottom shear due to ship traffic (in addition to natural currents); and ice influences. The effects of shipping are especially important since bottom stresses due to prop wash and/or direct hull contact at shallow sites are typically of a greater magnitude than the combined effects of waves and other currents. A windowing or templating technique has been used successfully in several Corps districts to overlay the effects of each site-selection parameter in an area, identifying graphically the optimal sites.

#### Modeling site influences

Numerical models have been developed (Johnson 1986) that can be used to estimate the initial configuration of a dredged material disposal mound on the sea floor. These models incorporate the dredged material characteristics and features of each of the six site evaluations considerations described earlier.

The models allow rapid and economical comparisons of the influence of site conditions at several locations under consideration for a disposal project or prediction of the effects of variations in operational technique or equipment at a selected site. A recent application, for example, allowed assessment of the effects of very deep water at a Puget Sound disposal site on the descent of the jet from a conventional surface release versus a submerged discharge.

### Summary

Capping is the controlled accurate placement of contaminated dredged material at a disposal site, followed by a covering or cap of clean isolating material. Capping projects are typically described as level-bottom placement or contained aquatic disposal. Field experience with subaqueous capping is limited, but eleven sites have been identified where the technique has been applied in one form or another (Table 2).

Site-selection considerations for capping projects are similar to those for any open-water disposal. The influences of several types of site characteristics on capping have been identified and discussed. Modeling methods are available to aid in evaluating sites and designs. Additional information on cap materials, placement, and monitoring are provided in Technical Note EEDP-01-4.

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